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$$a = 4.74 \times 10^{-8} \text{ cm.}; \; h = 6.65 \times 10^{-8} \text{ cm.}$$

$$d_{11\bar{2}0} = 3.79 \times 10^{-8} \text{ cm.}; \; d_{10\bar{1}0} = 2.37 \times 10^{-8} \text{ cm.}; \; d_{0001} = 3.32 \times 10^{-8} \text{ cm.}$$

The arrangement of the lattices is conveniently explained by referring the origin of each lattice to two unit axis making an angle of 120° and a third mutually perpendicular to these. The coordinates of the origins are then

$$0,0,0; \; \tfrac{1}{3},\tfrac{2}{3},1/z; \; \tfrac{1}{3},\tfrac{2}{3}, \; \tfrac{1}{2}; \; 0,0, \; (z + 2)/2z.$$

TABLE 6

VALUES OF $K$ AND CORRESPONDING APPROXIMATE VALUES OF $x$ WHEN $h$ = 14.75 CM.

| INDEX | $\phi$ | Sin $\phi$ | MODEL I | | MODEL II | | MODEL III | | MODEL IV | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | $K$ | $x$ | $K$ | $x$ | $K$ | $x$ | $K$ | $x$ |
| $10\bar{1}1$ | 58°18′30″ | 0.8509 | $\frac{1}{2}$ | 1.8 | 1 | 0.9 | 1 | 0.9 | 1 | 0.9 |
| $10\bar{1}2$ | 39° 9′ 9″ | 0.6293 | 1 | 1.2 | 1 | 1.2 | 1 | 1.2 | 1 | 1.2 |
| $10\bar{1}3$ | 28°22′ 0″ | 0.4751 | $\frac{1}{2}$ | 3.1 | 1 | 1.6 | 1 | 1.6 | 1 | 1.6 |
| $20\bar{2}1$ | 72°50′20″ | 0.9555 | $\frac{1}{4}$ | 3.2 | $\frac{1}{2}$ | 1.6 | $\frac{1}{4}$ | 3.2 | $\frac{1}{3}$ | 2.4 |
| $30\bar{3}1$ | 78°22′13″ | 0.9795 | $\frac{1}{6}$ | 4.5 | $\frac{1}{3}$ | 2.2 | $\frac{1}{6}$ | 4.5 | $\frac{1}{6}$ | 4.5 |
| $30\bar{3}2$ | 67°37′36″ | 0.9248 | $\frac{1}{3}$ | 2.6 | $\frac{1}{3}$ | 2.6 | $\frac{1}{3}$ | 2.6 | $\frac{1}{3}$ | 2.6 |
| $30\bar{3}4$ | 50°32′15″ | 0.7720 | $\frac{1}{3}$ | 2.9 | $\frac{1}{3}$ | 2.9 | $\frac{1}{3}$ | 2.9 | $\frac{1}{3}$ | 2.9 |
| $40\bar{4}1$ | 81°13′30″ | 0.9886 | $\frac{1}{8}$ | 6.6 | $\frac{1}{3}$ | 2.2 | $\frac{4}{9}$ | 3.3 | $\frac{1}{4}$ | 3.0 |

The values of $z$, that is the relative displacement of the two planes making up a basal pair, is uncertain and needs further investigation. This requires a careful determination of the relative intensities of the spectra of different orders reflected from the 0001 planes and was beyond the scope of the present investigation. Conditions of symmetry suggest a value of $z = 6$, but this is purely conjectural.

The investigation was pursued under the direction of Prof. A. G. Webster of Clark University in the Physics Laboratory of the Worcester Polytechnic Institute.

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[1] *Paris, C.-R. Acad., Sci.,* **157,** Nov. 17, 1913, (924–926).

[2] Dana, *System of Mineralogy,* 1888 ed., p. 205.

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# *FRINGING REEFS OF THE PHILIPPINE ISLANDS.*

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**Read before the Academy, April 23, 1918**

A series of large-scale charts recently published by the United States Coast and Geodetic Survey for certain parts of the Philippine islands are, apart from their value to commerce, of much scientific interest in connection with the coral-reef problem by reason of the great volume of carefully ascertained facts that they present. They are in various respects more detailed and more accurate than the Admiralty and Hydrographic Charts hitherto available. Many of the islands are thus shown to have more or less minutely embayed shore lines, indicative of the subrecent or recent submergence of an eroded land surface. This is particularly true of Palawan, the southwesternmost member of the group, which has a shore line of most intricate pattern where its western side is indented by Malampaya sound: there can be no question that the coastal features of this kind exhibited on Palawan and many other members of the Philippine group result from the recent partial submergence of an uneven land surface.

According to Darwin's theory of coral reefs, in the form usually presented, shores of submergence should be fronted by barrier reefs; but the Malampaya district of Palawan is not so fronted; its reefs, where they occur, belong to the fringing class, and since Darwin's time fringing reefs have been associated with stationary or emerging shores. Barrier reefs are indeed exceptional in the Philippines, in spite of the repeated occurrence of embayed shore lines on many islands, and the question therefore arises whether the theory of upgrowing reefs on intermittently subsiding foundations is incorrect or incomplete. The object of this paper is to point out that the theory, as ordinarily stated, is incomplete, and that the element needed to complete it is to be found in a seldom-quoted passage from Darwin's own writings, as follows: "If during the prolonged subsidence of a shore, coral-reefs grew for the first time on it, or if an old barrier-reef were destroyed and submerged, and new reefs became attached to the land, these would necessarily at first belong to the fringing class" (Coral Reefs, 124).

This passage may be understood as meaning that the "prolonged subsidence" of an island might be too rapid to permit reef growth, until a pause allowed the establishment of a fringing reef; and also that the rapid subsidence of an island would destroy and submerge a barrier reef previously formed around it during slower subsidence, whereupon a fringing reef would be formed on the new shore line. Thus interpreted, the passage affords a satisfactory explanation of the frequent association of fringing reefs with shore lines of submergence in the Philippines and in certain other archipelagoes, even though such reefs may elsewhere be found on stationary shore lines or on shore lines of emergence. Fringing reefs thus formed may be described as "of a new generation:" they will evidently lie unconformably on the eroded rocks of the shore belt, and their unconformity, as well as the embayments of the shore line, will indicate their association with submergence. The contact of fringing reefs with the marine sediments that ordinarily characterize a non-embayed shore line of emergence would be essentially conformable.

Whether the shores of the Philippines now for the first time have reefs formed upon them, according to the first clause in the above quotation from Darwin, or whether the existing fringes are the successors of "destroyed and submerged barrier reefs," according to the second clause, may be determined for certain islands by the abundant off-shore soundings. Thus in the case of Palawan, its embayed western coast does not descend rapidly to great depths, but is fronted by a well defined submarine platform, 20 or 30 miles wide, along the seaward edge of which a discontinuous rim rises towards but not to the surface; the rim can be most reasonably explained as an incomplete upgrowth from a barrier reef of an earlier generation on the outer margin of a broad lagoon. It is not possible, in our present ignorance of the geology of Palawan, to determine whether the drowned barrier reef was formed by upgrowth during slow and long continued subsidence, or by outgrowth during a long-enduring still-stand of the island; but in either case, the great breadth of the lagoon plain appears to be the product of a long lasting process, and thus contrasts strongly with the new fringing reefs of the Malampaya district, which are so narrow as to be inconspicuous on charts of the largest scale. Evidently, therefore, the rapid submergence by which the barrier reef of Palawan was drowned must be of recent date.

Similar conclusions may be derived from other parts of the Philippines, where embayed shore lines, relatively narrow fringing reefs, and well defined submarine platforms are frequently found, although no islands are so striking in these respects as Palawan. The platforms cannot be reasonably ascribed to marine abrasion during a higher stand of the islands or a lower stand of the ocean, for the island shores are not clift; and the submergence of the platforms cannot be accounted for by a rise of ocean level, which must everywhere be of the same date, amount and rate, for the platforms vary in depth, and the new fringing reefs vary in breadth. The depth of the Palawan platform for example, increases from 25 or 30 fathoms at its southwestern end to 55 or 60 fathoms near its middle, and then decreases again toward the northeastern end; and the fringing reef, which is hardly chartable near the mid-length of the island where the platform is deep, has a width of 1 or 2 miles at the southwestern end of the island where the platform is relatively shallow.

On the other hand, the northeastern coast of Samar, on the opposite side of the archipelago from Palawan, has a moderately sinuous shore line with delta flats that diminish the initial size of its bays, and fringing reefs that reach forward a mile or so from its points; here the latest submergence cannot be so recent as that of Palawan. But instead of being benched by a submerged platform, the sea bottom off shore from Samar sinks rapidly to a great depth. Moreover, there are long stretches of the coast of Luzon which are neither embayed by arms of the sea, nor enclosed by barrier reefs, nor fronted by submarine platforms: Luzon, unlike many other of the Philippines, has a considerable extent of coastal lowlands, as if the growth of fringing reefs, or the outwash of detritus, or the emergence of the former sea border had increased its low littoral area. Again, Cebú and Negros, which occupy a somewhat central position in the archipelago, are described by Becker as terraced with elevated reefs up to altitudes of 2000 feet or more. The diverse shore features of the different islands are therefore best explained by local changes of land level, unlike in date, in direction, in amount and in rate.

It is particularly the rapid rate, the recent date, and the considerable amount of subsidence often indicated that are of significance in the coral-reef problem; and this is true not only for the Philippines but also for the other archipelagoes between Asia and Australia. Embayed shore lines indicative of submergence are common though by no means universal in all this region, but well developed barrier reefs are rare. Before the reefs of Cebú and Negros were elevated, and before the platform of Palawan was depressed, barrier reefs must have been more extensive than now in the Philippines, and possibly in the other island groups also; but today no examples of these forms are to be found in the archipelagoes that can compare with the great barrier reefs of northeastern Australia and of New Caledonia; few of the many small islands in the archipelagoes are enclosed by well developed encircling reefs, like those of the Fiji and Society groups; and atolls, which are so striking a feature of the open Pacific, are relatively uncommon in the archipelagoes.

The best explanation of the small development of barrier reefs and atolls in the archipelagoes is to be found, not in the lack of subsidence, which is elsewhere so intimately associated with reef development, for geological and physiographic evidences of subsidence abound on many islands; and surely not in the prevalence of unfavorable conditions as to the temperature and purity of sea water, for fringing reefs flourish; but largely in the occurrence of subsidence of so rapid a rate and in some cases of so great an amount, as to have submerged pre-existing reefs. Moreover the subsidences appear to be in many cases of so recent a date that the new fringing reefs are still narrow; it is presumably for this reason that the drowned barrier reefs and atolls have not yet had time to grow up again to sea level. Added to this is the frequent occurrence of recent uplifts in the archipelagoes, whereby weak marine sediments, overwashed by an abundance of alluvium from rejuvenated rivers, have come to occupy the shore line of certain islands, thus discouraging even the growth of fringing reefs, as around much of the coast of Borneo and along the southern coast of Java; but this aspect of the problem cannot be discussed here.

In view of these facts and inferences the Australasian archipelagoes must be considered much more unstable than the floor of the central Pacific. In that vast region, where reef upgrowth has generally kept pace with changes of level, and where atoll and barrier-reef lagoons have been filled with sediments to a moderate depth, Darwin appears to have been right in concluding that "the subsidence thus counterbalanced must have been slow in an extraordinary degree" (115). Not only movements of depression but modern movements of elevation also have been of moderate measure in the central Pacific, for none of the occasional elevated atolls found there have an altitude of more than a few hundred feet: it is only in Tonga and Fiji that greater measures of modern uplift are recorded, the greatest altitude of a reef in Fiji being 1030 feet: uplifted reefs in the Australasian archipelagoes are found at altitudes of 2000 and 3000 feet.

On the other hand, the instability of the Australasian region is attested not only by the evidence afforded by coral reefs, but also as above noted, by many geological researches; those by Molengraaff and Abendanon are particularly instructive in this respect, and fully confirm Darwin's statement:—"North of Australia lies the most broken land of the globe, and there the rising parts are surrounded and penetrated by areas of subsidence" (143). Hence while Darwin's general conclusion that "the rate of subsidence has not exceeded the upward growth of corals" (115) seems to hold true for the central Pacific, it is not valid for the region of the archipelagoes. The not infrequent occurrence there of subsidences at a rate sufficient to drown coral reefs ought to satisfy those objectors to Darwin's theory who have urged that it demands too great a uniformity, if not also too slow a rate in the movements of the earth's crust in oceanic areas. But let it be noted that rapid movements of subsidence, and also fringing reefs of a new generation which are formed along a shore where rapid subsidence had drowned pre-existing reefs, were explicitly recognized by Darwin as of possible occurrence—witness the first quotation from his Coral Reefs, above.

Fringing reefs of a new generation on shores of submergence should therefore be accepted as accounted for by Darwin's theory quite as well as other fringing reefs, and indeed as contributing their share towards verifying the theory, even though its author did not recognize any actual fringing reefs as of this origin. He colored all fringing reefs red on his chart, as indicating non-subsiding coasts; for even after pointing out the possibility of their formation where "prolonged subsidence" has taken place, he added: "I have no reason to believe that . . . . any coast has been coloured wrongly with respect to movement indicated" (124). His information about the Philippines was scanty; he colored all their fringing reefs red, as indicative of stationary or rising coasts.

There can indeed be little doubt that a number of other islands also, which have unconformable fringing reefs along their embayed shores, were wrongly classed by Darwin, who took no account of embayments or of unconformities. Striking instances of this kind might be pointed out in the Solomon group, where the small island of Fauro, for example, which is described by Guppy as a deeply denuded volcanic wreck, has a shore line of marked irregularity, a narrow fringing reef, and a well developed submarine platform from 40 to 70 fathoms in depth: such a combination of features proclaims intermittent subsidence after long-continued subaerial erosion, the last movement being more rapid than reef upgrowth; yet all the members of the Solomon group are colored red on Darwin's chart, because the little information he had about them gave "a presumption that they are fringed" (167). Other examples of new fringing reefs on shores of submergence are found on the granitic islands of the Seychelles in the western Indian ocean, as will be again noted below. The

Andaman islands in the Bay of Bengal are elaborately embayed, and a submarine platform several miles in breadth and from 20 to 40 fathoms in depth adjoins them; a bank of similar depth, measuring 35 by 10 miles lies not far away to the east; yet these islands have no barrier reefs and only very narrow and discontinuous fringing reefs; their submergence must be very recent. If the postglacial rise of ocean level were the cause of all these submergences, reefs should everywhere be of about the same volume: as a matter of fact they vary in volume enormously. The fringing reefs of southwest Palawan, of Yap in the western Pacific, and of Rodriquez in the southern Indian ocean are two or three miles wide; various atoll and barrier reefs are half a mile or a mile wide. Others are much narrower, and still others are discontinuous, or so imerfectly developed as not to reach sea level: finally, some submarine banks are flat, without any reef rim. These irregular values speak for variable subsidence of the reef foundations, not for a uniform rise of ocean level.

The occurrence of subsidence in the Australasian region at a more rapid rate than that of coral upgrowth has an interesting bearing on the origin of the numerous submarine banks, of various depths down to 40, 50, or 60 fathoms, in the China sea. It is evident that if islands suffer a movement of subsidence rapid enough to drown their barrier reefs and thus to develop fringing reefs of a new generation, the same subsidence would completely submerge neighboring atolls. Furthermore, if the rapid subsidence of a group of islands were of so recent a date that the resulting fringing reefs are still narrow, the drowned reefs of the submerged atolls might still remain below sea level, even if the amount of submergence had not been great enough to kill all their corals.

Now in view of the proximity of the China sea to the Philippine Islands, it seems reasonable to suppose that its floor has shared some of the many movements by which the islands of the archipelago have been disturbed; hence the submarine banks of that deep basin are best explained, following Darwin's theory, as drowned atolls not yet rebuilt. The date as well as the rate and the amount of a subsidence is therefore of importance in determining whether the atolls that it drowns shall still be submerged. Certainly recent submergence, presumably due to subsidence, has affected the Macclesfield and certain other large submarine banks of the China sea, for corals are growing on the rims of many of them, but have not yet built the rims up to the sea surface. On the other hand in spite of the proximity of the unstable Philippines, the Glacial-control theory explains the Macclesfield bank, which is taken to be a typical example of its kind, as the remains of a huge volcanic cone, originally as large as Hawaii, which stood still long enough to be worn down to small relief in preglacial time, and which, still fixed, was truncated by abrasion at a lower level while the ocean was depressed about 40 fathoms during the Glacial period. So long enduring a stability seems improbable enough even for the central Pacific, and much more improbable for a next-door neighbor of the Philippines.

It may be noted that if the surface forms of the mid-Pacific atolls are considered alone, they can be accounted for very satisfactorily by the Glacial-control theory,, which was invented chiefly to explain the special features that they present: but as atolls occur in association with barrier reefs in the Caroline, Society, Fiji and other groups, and as the central islands within the barrier reefs present features which, although perfectly accounted for by Darwin's theory of intermittent subsistence, cannot be accounted for by the Glacial-control theory, its apparent success in explaining atolls is thereby discredited, all the more so in view of the recent discussion by Skeats of the boring in the Funafuti atoll (*Amer. J. Sci., New Haven,* **45,** 1918, 81–90).

The chief value of the ingenious Glacial-control theory may therefore be found not so much in its postulate of the prevalent stability of reef-bearing islands, or in its assumption that reef corals were killed and that reef-bearing islands were abraded while the ocean was chilled and lowered in the Glacial period, but in the emphasis that it gives to changes of sea level from climatic causes as a factor in the coral-reef problem; for it is manifest that if the post-glacial rise of sea level coincide in time with the subsidence of an island, the resulting submergence will be at an accelerated rate and of an increased amount; while if the fall of sea level occasioned by the oncoming of a glacial epoch coincide with a subsidence, the resulting submergence will be at a retarded rate and of a decreased amount. It cannot however be supposed that two processes so unlike in cause as external climatic changes and internal crustal deformations should be closely related in time; their coincidences must be fortuitous. Throughout the central Pacific the rate and amount of recent submergence have not been as a rule too great to be compensated by reef upgrowth; witness the abundant atolls and barrier reefs. But in the region of the Australasian archipelagoes compensation of submergence by reef upgrowth has frequently been unsuccessful; witness the rarity of well developed barrier reefs and the almost entire absence of atolls. As the climatic changes of ocean level must have been everywhere the same, the factors which have determined the success or the failure of reef upgrowth would appear to be the rate, the amount and the date of subsidence.

It may be added that submarine banks, of such form that they are best accounted for as drowned atolls, are rare in the Pacific. A group of ten or more of them is known in an island-free space north of Fiji: several extensive banks also occur in Tonga. Exception must therefore be made in favor of a rapid submergance only for these relatively few examples of submerged Pacific atolls, and the rule that the great majority of Pacific atolls have not been submerged faster than the rate of reef upgrowth is thereby proved. In the Indian ocean, on the other hand, the number of submarine banks bears a larger proportion to that of atolls, and the Indian ocean is generally regarded by geologists as the seat of greater and more recent movements of depression than the Pacific. Recent and rapid subsidences of moderate amounts may therefore be plausibly regarded as of more general occurrence in the Indian than in the Pacific ocean. The recent date and the rapid rate of subsidence appear to be of greater importance than its amount in the case of the Great Chagos bank, where the submergence does not seem great enough to drown the reef-building corals. Here the muddy central area is 40 or 50 fathoms deep; it is bordered by an irregular sandy bank from one to 5 miles or more in breadth and from 15 to 20 fathoms in depth, on the outer margin of which rises a rim about a mile in width, and only 5 or 10 fathoms in depth; singularly enough, there is little living coral on the outer rim, though knobs of growing coral rise from the central depression. The diameters of the whole mass range from 50 to 75 miles: its form suggests that a prolonged stationary period, during which a broad atoll-reef was developed, was followed by a subsidence of about 10 fathoms, after which a shorter stationary period permitted the upgrowth of a narrower reef; then a rapid and presumably recent subsidence of 5 or more fathoms ensued, since which no effective reef growth has taken place, possibly because, according to Daly's suggestion, the submerged corals were smothered by wave- and current-shifted sediments.

Unfortunately no archipelagoes comparable to those of the Australasian region are present in the Indian ocean to give evidence in the case, but it may be noted that a few high islands which occur in association with the Indian ocean banks—chiefly the granitic islands in the area of the great Seychelles bank—have narrow and unconformable fringing reefs on their deeply eroded and well embayed shores; thus they repeat in a small way the more abundant and therefore more compulsory evidence that is provided by the charts of the Philippines. Further details on these topics are given in an article on "Submarine Banks and the Coral Reef Problem," now in course of publication in the *Journal of Geology*, and in an article on the "Subsidence of Reef-encircled Islands," soon to appear in the *Bulletin of the Geological Society of America*.

# DILATION OF THE GREAT ARTERIES DISTAL TO PARTIALLY OCCLUDING BANDS

By William S. Halsted

Medical School, Johns Hopkins University

Read before the Academy, April 22, 1918

The incentive to the work was primarily the desire to cure aneurysms of the abdominal aorta and common iliac arteries.

The method usually employed for the cure of aneurysm is the simplest, viz., the ligation of the affected artery proximal and as close as feasible to the aneurysm. The aorta has been ligated 25 or more times in man, and always with fatal result. Death has been due to hemorrhage or overtaxed heart. Neither gangrene nor paraphlegia has ever resulted from ligation of the aorta